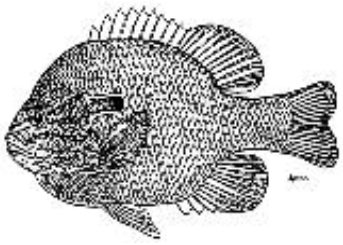
Numerical Classification Analysis of Sediment Chemistry Collected by Triad Engineering Inc., Walnut Creek, Kosciusko County, January 2003



Indiana Department of Environmental Management
Office of Water Quality
Assessment Branch
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Abstract

The Indiana Department of Environmental Management, Office of Water Quality, Assessment Branch has selected an objective method to characterize sediment chemistry independent of the sediment layer characterization used by Triad Engineering where a probe was used to define and identify sediment characteristics. This study used the Triad Engineering's chemistry data to define similar chemistry patterns within the data sets. Twelve chemistry parameters were used to characterize each sediment sample: total volatile solids (TVS), total organic carbon (TOC), ammonia (NH3-N), total Kjeldahl nitrogen (TKN), nitrogen (NO2+NO3-N), total phosphorus (Total-P), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn). Each parameter was normalized using four quartile categories designated 1, 2, 3, 4 with the scale going from low concentration to high. Multivariate analysis was conducted on the normalized data using an Euclidean Distance similarity index followed by an evaluation using Ward's clustering method. Seven contamination subgroups were identified, nested within two major groups. Eight of the twelve chemical parameters proved to be descriptive for each of the contamination groups (TVS, TKN, Cr, Cu, Pb, Hg, Ni, and Zn). The two major groups (highly contaminated subgroups 1, 2, 3 and 4, and minimally contaminated subgroups 5, 6, and 7) were tested to determine statistical differences. The two major groups were significantly different ($p<0.001$, $\alpha = 0.05$) across all eight parameters. Mean concentrations for the samples identified in the seven contamination subgroups were further characterized to determine if observed gradients across subgroup means were statistically significant. The observed gradient was significant across six of seven contamination subgroups and across all eight chemical parameters with significant regression coefficients (r^2) ranging from 0.49-0.97 and p-values ranging from <0.001- 0.047. The only gradient not significant across all subgroup means was TVS, which dropped out of significance, for one subgroup at the highest contamination end of the gradient. The decrease in TVS in this subgroup is explainable based on the physical location of the samples and demonstrates the usefulness of this objective exploratory data analysis. The gradient is significant if this subgroup is dropped. Group means of the two major groups were used to evaluate their use as restoration reference points (RRP). The suggested RRP concentrations for metals were most comparable to the regional background means as determined by an aquatic surficial sediment model used to characterize such sediment contamination in the State. This characterization provides an objective, statistically defensible characterization of Walnut Creek sediment that can serve as an objective method to establish remediation endpoints below the Warsaw POTW.

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INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER QUALITY
ASSESSMENT BRANCH
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INTRODUCTION

Numerical classification analysis is a multivariate exploratory data technique that can objectively determine patterns in complex data sets, allowing the investigator to objectively reorganize observed data into meaningful arrangements that can be further explored. These techniques have had widespread use in the environmental field for many decades (Boesch 1977, Ludwig and Reynolds 1988, Manly 1994).

While the computational considerations are complex, the concept is quite simple. If an investigator has many rows of data with many columns of numbers across many numerical scales, the complexity quickly exceeds the investigator's mental ability to observe patterns. The use of multivariate techniques allows the investigator to objectively examine all columns and all rows of data in all possible combinations, identify the similarities, and allow the observations to be reorganized to reflect these identified patterns (Clifford and Stephenson 1975; Ludwig and Reynolds 1988). In data sets with identifiable numerical patterns, once the patterns have been identified, these patterns can be used to further explore the data. Simply stated, numerical classification analysis is a way to rearrange groups of numbers to find and identify similar patterns in the number groups.

This data analysis provided an informative picture of sediment data collected in proximity of the Warsaw Public Owned Treatment Works (POTW) and allowed the level of contamination of the sediments to be identified and characterized. The results of this numerical classification analysis were e-mailed to Tina Reese, of Triad Engineering on March 25, 2003.

METHODS

Basic exploratory data analysis methods were used to numerically classify sediment chemistry results submitted by Triad Engineering. Calculations of quartiles, multivariate cluster analysis, regression analysis and graphic interpretations were conducted using Statistica™ 6.1 Software (StatSoft, Inc. 1984-2003). All chemical parameter units are in mg/kg (ppm) (dry weight) except for Total Solids (TS) and Total Volatile Solids (TVS) which are in percent (%).

Data analysis consisted of seven steps:

1. Parameters for analysis were selected.

Twelve parameters were selected for analysis: total volatile solids (TVS), total organic carbon (TOC), ammonia (NH3-N), total Kjeldahl nitrogen (TKN), nitrogen (NO2+NO3-N), total phosphorus (Total-P), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn).

2. Restructured or normalized sediment analytical data to a uniform numerical scale.

The median, 25th and 75th percentiles were determined for each parameter based on sediment results provided. Each parameter was normalized to four categories based on quartiles (Table 1). Values below the 25th percentile received a score of 1, between the 25th percentile and median a 2, between the median and the 75th a 3, and greater than the 75th percentile received a score of 4.

3. Cluster Analysis conducted to identify similarities of underlying numerical structure within the sediment chemistry data.

A quantitative Euclidean Distance similarity index (Boesch 1977; Clifford and Stephenson 1975; Ludwig and Reynolds 1988) was utilized to identify similarities in the analytical results. This similarity index identifies patterns in a multivariate manner. The methodology continues to examine, in a step-by-step manner, all possible combinations of columns and rows of data, presenting results in a graphical representation of the degree of similarity called a Hierarchical Tree Plot (Figure 2) (Ward 1963). This clustering method is distinct from most clustering methods because it uses an analysis of variance approach to evaluate the distances between clusters minimizing the Sum of Squares of any two (hypothetical) clusters that can be formed at each step. This clustering method is regarded as very efficient and has come under wide usage in the literature due to its versatility (StatSoft, Inc. 1984-2003).

Seven subgroups, within two major groups were selected for further analysis based on the relative difference between the groups. These seven subgroups are referred to as "contamination groups" since they represent a scalar relationship of contamination, ranging from 1 (the most contaminated) to 7 (the least contaminated)(Figure 2).

4. Contamination subgroups identified by assigning a subgroup membership of 1-7.

Group assignment to each sample allowed the data (rows) being reorganized to observe the numerical patterns identified (Table 2). It is at this point that the multivariate patterns of numerical similarity can best be observed in the data.

5. Examined the raw chemistry data, in their original parameter-specific concentrations relative to contamination group membership.

Mean values and variance for each chemistry parameter was examined to determine which chemical parameters were unique to the contamination group. These data are presented as a series of box-and-whisker plots.

6. Selected eight of the twelve original chemical parameters that uniquely identified the contamination groups (TVS, TKN, Cr, Cu, Pb, Hg, Ni, and Zn). Conduct Regression Analysis and Mann-Whitney U test to determine if the eight chemical parameters selected were statistically different between the seven contamination subgroups and/or between the two major groups (subgroups 1, 2, 3, and 4 representing the highly contaminated group; and subgroups 5, 6, and 7 representing the minimally contaminated group). Metal concentrations of the groups were compared to background concentrations of region-specific aquatic surficial sediment model concentrations using Wente (1994).

7. Determined restoration reference points (RRP) based on findings in Step 6 above.

RESULTS

The 55 sediment samples and associated analytical chemistry results taken from Walnut Creek in January 2003 by Triad Engineering provided a unified data set from which to examine sediment chemistry above and below the Warsaw POTW. Figure 1 demonstrates a strong relationship between the Total Solids and Total Volatile Solids, in these samples. This relationship extends out to 30% TVS with one outlier at 40%; suggesting that a wide and typical characteristic range of TVS conditions were represented.

The objective, unbiased, numerical classification analysis using the Euclidean Distance similarity index identified underlying similarities in sediment chemistry based on multivariate relationships of the twelve chemical parameters.

Figure 2 illustrates that two major groups have been identified with an 80% relative difference. In addition, seven distinct subgroups can be observed which have similar and identifiable chemical characteristics (Figure 2). The greater the similarity of the twelve scoring numbers which represent the original chemistry data, the closer the samples would be to each other on the x-axis. The vertical nodal distance for any sample on the y-axis will be the relative similarity of the sample or group of clustered samples. While this occurs in multivariate space (multidimensional space) the pattern is quickly apparent. On the Y-axis at the zero point of the scale (bottom) all samples are 0% similar and at the 100 point (top) of the y-axis all samples are 100% similar. (Conversely stated 100% dissimilar and 0% dissimilar respectively). While the percent relative difference between the two major groups is 80%, the percent relative difference is less between the seven designated contamination subgroups. The seven contamination subgroups are scalar from contamination subgroup 1, which is the most contaminated, to contamination subgroup 7, which is the least contaminated.

Two distinct groups are identified (Figure 2) and designated "highly contaminated" (subgroups 1, 2, 3 and 4) and the second designated "minimally contaminated" (subgroups 5, 6, and 7). Within the highly contaminated group, subgroup 4 is transitional having characteristics of both the minimally contaminated subgroups and highly contaminated subgroup.

Once the multivariate structure of the data was identified, the original chemistry was examined to determine which chemical parameters were most descriptive of the designated groups. Mean values for each parameter were examined to determine which chemical parameters were characteristic of the contamination groups. Figures 3 -16 reflect the means for each of the twelve chemical parameters. Of the twelve original chemistry parameters, eight proved to be minimally overlapping and possibly statistically different, to various degrees across both levels of group designations. These parameters include TVS, TKN, Cr, Cu, Pb, Hg, Ni, and Zn.

Before statistical significance was tested it was apparent that all eight chemical parameter across the seven contamination subgroups presented an observable gradient across subgroup means (Figures 4, 8, and 11-16). Also apparent was the two-group designation which had an even

stronger difference if the 1-7 contamination subgroups were clumped into two groups (minimally contaminated and highly contaminated).

Statistical evaluation of both designated groups was done to determine if the groupings were statistically defensible and represented a definable contamination group. The mean for each of the two major groups (highly contaminated subgroups 1, 2, 3 and 4, and minimally contaminated subgroups 5, 6, and 7) were tested using a Mann-Whitney *U* test. All eight chemical parameters were highly significant in their difference ($p<0.001$, $\alpha = 0.05$) between the two groups (Figure 2).

Mean concentrations for samples identified in the seven contamination subgroups were further characterized to determine if the observed gradients across subgroup means were statistically significant. Linear regression analyses were conducted across all eight gradients as established by the means (log linear for metals) of the seven subgroups. The observed gradients were significant across six of seven contamination subgroups and across all eight chemical parameters with significant regression coefficients (r^2) ranging from 0.49-0.97 and p-values ranging from <0.001- 0.047. The only gradient not significant across all subgroup means was TVS, which dropped out of significance for one group at the highest contamination end of the gradient. The decrease in the TVS mean for this subgroup is explainable based on the physical location and *in-situ* oxidation-reduction of the samples. Subgroup 1 consisted of eight sediment samples of which 4 were located deep in the stream where the TVS associated with the high contamination of metals has most likely oxidized to a much lower TVS concentration. This observation with others demonstrates the usefulness of this objective exploratory data analysis.

Once two distinct, statistically separate groups of sediment contamination levels were identified, it was possible to evaluate the means and variance (+/- one standard deviation) of the eight individual chemical parameters and determine a representative restoration point for each chemical parameter.

Wente (1994) presents regional statistical values for aquatic surficial sediments collected by IDEM throughout the state of Indiana. These data were collected over a period of time (1984-1995) and the data were typically collected in proximity to suspected pollution sources. As such the mean and 95th percentiles expressed in the Wente Model have been pushed to the contaminated end of a background concentration continuum. The mean value for Koskiusko County was determined by graphic interpolation of the figures in Wente (1994) and used the 95th percentile for comparative purposes in the figures in this report. After analyzing the chemistry results of the 55 samples collected by Triad Engineering (Appendix A), the following recommendations are suggested for remediation reference. These restoration reference points (for metals) are most comparable to the regional background means as determined by an aquatic surficial sediment model (Wente 1994) used to characterize such sediment contamination in the State.

CONCLUSIONS

Based on mathematical breaks in the sediment chemical data, seven different "contamination subgroups" have been identified and characterized. Also, that eight chemical parameters could

serve as minimally overlapping benchmarks for the identification of uncontaminated to marginally contaminated sediment of the Walnut Creek substrate and thus serve as restoration reference points (RRP).

A Mann-Whitney *U* test determined that all eight chemical parameters are statistically significant ($p<0.001$, $\alpha = 0.05$) when examined as two separate groups (contamination subgroups 1, 2, 3, 4, the highly contaminated group; and 5, 6, 7, the minimally contaminated group) providing two points of reference from which sediment in Walnut Creek can be characterized.

While statistical differences between the eight chemical parameters and the seven contamination subgroups varies, individual trend lines between subgroup means in box and whisker data presentations are obvious (Figures 4, 8, and 11-16). Regression analysis of the subgroup means indicate that six of the seven identified gradients are statistically significant with regression coefficients (r^2) ranging from 0.49-0.97 and p-values ranging from <0.001- 0.047. The only gradient not significant across all subgroup means was TVS, which dropped out of significance for one subgroup at the highest contamination end of the gradient, but is easily explained by the data. This gradient becomes significant when this subgroup is dropped from the linear model.

This exploratory data analysis method defined and characterized the sediment samples in an objective and unbiased manner. It is possible, and informative, to go back to the Triad Engineering sample locations and interpret these subgroups based on the location of the sediment collection. When the contamination groups and subgroups identified in this study are examined spatially in the context of maps provided by Triad Engineering, samples in each contamination category are easily explained relative to their spatial distribution. This is explainable in an upstream and downstream pattern within the Walnut Creek system and vertically in their cross-section position within the stream. Figure 3 indicates that depth of sediment collected is not a usable indicator since the average depth of collection of the most contaminated sediments are similar to the average depth of the least contaminated sediments. The objective nature of this exploratory data analysis provides an unbiased interpretation of the data.

The two separate groups as identified by the Mann-Whitney *U* test (the highly contaminated group of subgroups 1, 2, 3, 4; and minimally contaminated group of subgroups 5, 6, and 7) provided two points of reference from which sediment in Walnut Creek can be further characterized. The mean and range of one standard deviation for all eight chemical parameters are presented. These ranges are referred to as the restoration reference points (RRP).

TVS	4 - 7 %	(mean 5)	Pb	7- 11 mg/kg	(mean 9)
TKN	423 - 838 mg/kg	(mean 630)	Hg	0.02 - 0.05 mg/kg	(mean 0.03)
Cr	12 - 29 mg/kg	(mean 20)	Ni	7 - 14 mg/kg	(mean 10)
Cu	7 - 13 mg/kg	(mean 10)	Zn	19 - 33 mg/kg	(mean 26)

These end points generally compare to the Wente (1994) mean values for metals in the watersheds of Kosciusko County. These values can be noted on the individual figures where the 95th percentile and the mean values are presented as well as the suggested restoration reference points identified in this study. (Figure 4, 8, and 11-16).

These suggested RRPs are based on an unbiased examination of the numerical structure of the sediment chemistry data collected by Triad Engineering in January of 2003. These RRPs do not

take into consideration toxicity endpoint, etc. These limits do assure that the sediments, if restored to these levels, would represent the former natural substrate chemistry of the natural sand/gravel bottom of Walnut Creek.

RECOMMENDATIONS

The origin of the entire 30,000 cubic yards of contaminated sediment below the Warsaw POTW is problematic. The TVS component of this sediment, downstream of the Warsaw POTW is obviously associated with chemical contaminants in identifiable concentrations above expected background concentrations for the region. The City of Warsaw and Triad Engineering should use the above-identified parameters and restoration standards for developing remediation strategies for the removal or mitigation of the contaminated or contaminating sludge from Walnut Creek. The remediation of this sediment in conjunction with proper compliance of the Warsaw POTW in the future will return Walnut Creek to its once productive condition and will protect the Tippecanoe River, which is considered the 8th most important river in the entire country, for preserving imperiled aquatic species.

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Figure 1: Relationship of Total Solids (%) and Total Volatile Solids (%) Walnut Creek Sediment

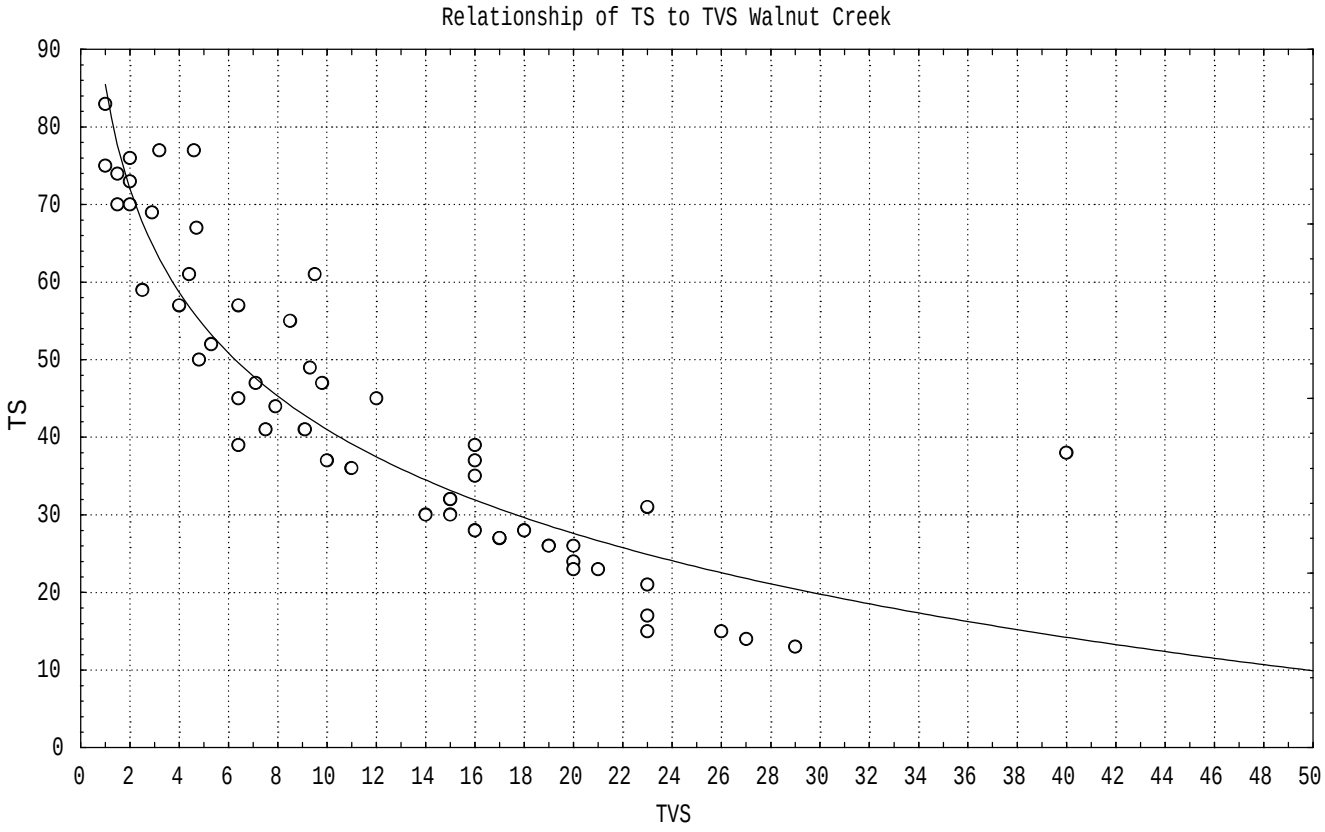


Table 1: Concentrations (mg/kg) Used for Scoring Criteria Based on the Median and the 25th, and 75th Percentile. Classification Score Break Points Based On Triad's Walnut Creek Sediment Data Quartiles (n=55)

Parameter	Score 1	Score 2	Score 3	Score 4
TVS (%)	≤ 4.7	> 4.7 ≤ 10	> 10 ≤ 19	> 19
TOC (%)	≤ 5.0	> 5.0 ≤ 10	> 10 ≤ 486	> 486
NH3-N	≤ 34	> 34 ≤ 92	> 92 ≤ 160	> 160
TKN	≤ 600	> 600 ≤ 1300	> 1300 ≤ 1700	> 1700
NO2+NO3-N	≤ 0.26	> 0.26 ≤ 0.31	> 0.31 ≤ 0.44	> 0.44
Total-P	≤ 110	> 110 ≤ 150	> 150 ≤ 260	> 260
Cr	≤ 12	> 12 ≤ 31.9	> 31.9 ≤ 57.6	> 57.6
Cu	≤ 7.05	> 7.05 ≤ 19.0	> 19.0 ≤ 28.0	> 28.0
Pb	≤ 7.8	> 7.8 ≤ 13.0	> 13.0 ≤ 27.7	> 27.7
Hg	≤ 0.02	> 0.02 ≤ 0.0635	> 0.0635 ≤ 0.144	> 0.144
Ni	≤ 7.48	> 7.48 ≤ 13.3	> 13.3 ≤ 42.6	> 42.6
Zn	≤ 20.0	> 20.0 ≤ 61.5	> 61.5 ≤ 115.0	> 115.0

Figure 2: Numerical Classification Analysis Results of Based on Table 1 Scoring Criteria

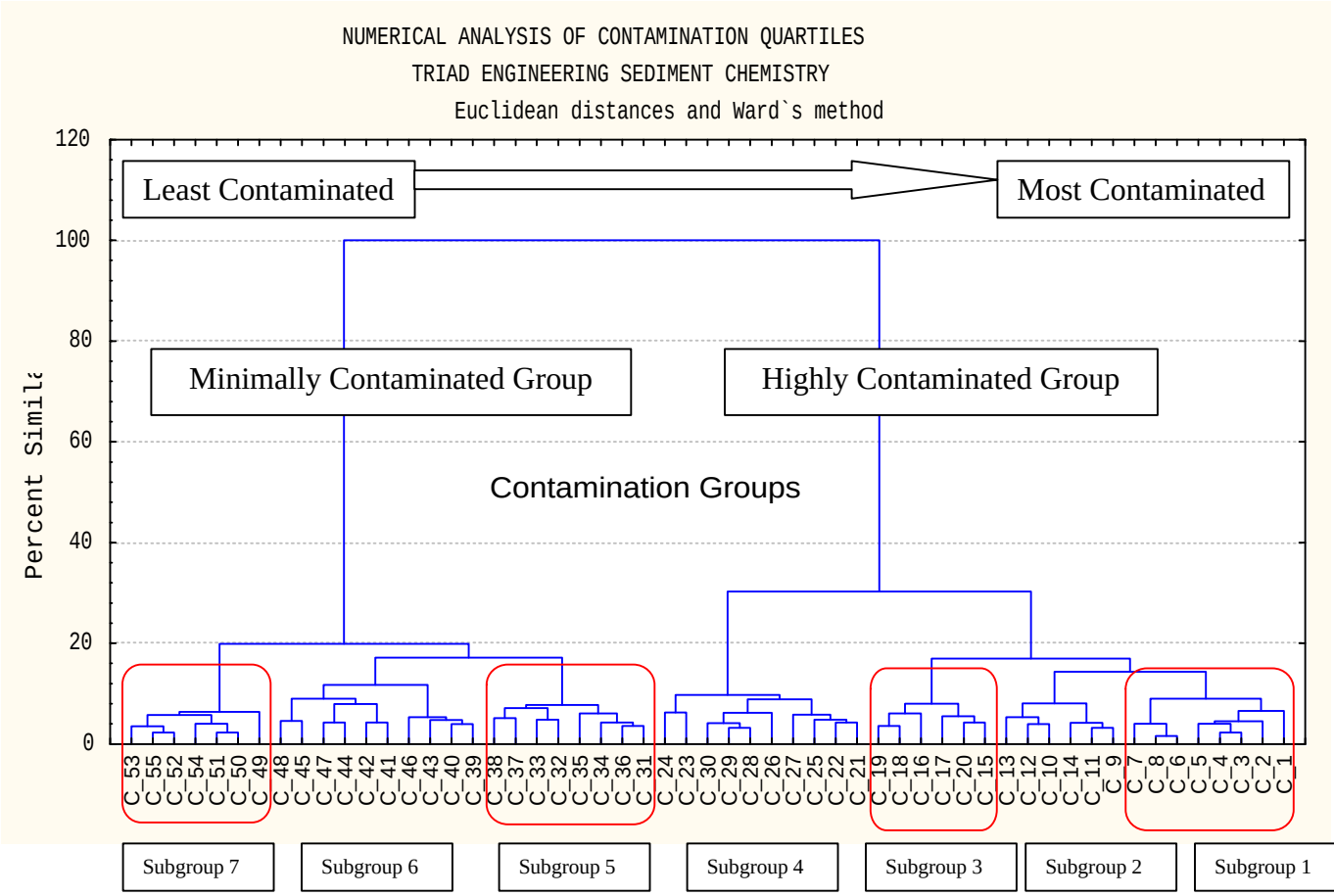


Table 2: Sediment Data Arranged to Reflect Numerical Classification Similarity and Contamination Group Membership (GRP)

TRIAD ENGINEERING SEDIMENT CHEMISTRY RESULTS

GRP	ord	depth	site	TVS	TS	TOC	NH3-N	TKN	NO2+NO3-N	T-P	Cr	Cu	Pb	Hg	Ni	Zn
1	1	3.15	SS-C-23A	1	67.0	1	3	2	1	2	4	4	4	4	3	3
1	2	3.2	SS-C-12AD	2	50.0	3	2	2	1	3	4	4	4	3	4	4
1	3	3.2	SS-C-12A	2	39.0	3	3	3	3	3	4	4	4	4	4	4
1	4	1.2	SS-C-24A	2	49.0	2	3	3	2	3	4	4	4	4	4	4
1	5	0.25	SS-R-9	3	36.0	4	3	3	2	2	4	4	4	4	4	4
1	6	3.6	SS-C-27B	3	37.0	2	2	4	2	4	4	4	4	4	4	4
1	7	1.75	SS-C-25A	3	28.0	2	4	4	2	4	4	4	4	4	4	4
1	8	2.1	SS-C-27A	4	26.0	2	2	4	2	4	4	4	4	4	4	4
2	9	0.25	SS-L-14	3	39.0	4	4	4	3	4	3	3	4	3	4	4
2	10	3.2	SS-L-16A	3	45.0	3	3	2	3	2	3	2	3	4	3	3
2	11	2	SS-L-10A	3	35.0	4	4	4	3	3	3	3	3	4	4	3
2	12	0.25	SS-L-10	3	30.0	4	3	2	3	3	3	3	3	3	4	4
2	13	0.25	SS-R-5	4	38.0	4	3	2	4	2	3	4	4	2	4	4
2	14	1.25	SS-R-9A	4	31.0	4	4	4	2	3	4	4	3	3	4	3
3	15	2.1	SS-C-31	3	27.0	2	1	3	3	2	4	3	4	4	3	3
3	16	2.9	SS-C-28A	3	26.0	2	1	3	2	2	3	3	3	1	3	4
3	17	2.25	SS-C-26A	3	26.0	2	1	4	1	2	4	4	4	4	4	4
3	18	0.25	SS-C-28	4	15.0	2	1	3	1	3	2	4	3	3	2	3
3	19	1.1	SS-C-27	4	23.0	2	2	3	1	4	3	3	3	3	3	3
3	20	0.75	SS-C-26	4	24.0	1	1	4	3	1	3	3	3	3	3	3
4	21	0.25	SS-C-12	3	32.0	4	4	3	2	4	2	2	2	3	2	2
4	22	0.25	SS-R-11	3	30.0	3	4	3	1	4	2	2	4	3	2	3
4	23	0.1	SS-C-21	3	27.0	1	3	2	2	4	1	1	1	3	1	1
4	24	0.1	SS-C-21D	3	28.0	1	3	2	3	4	2	2	3	3	3	3
4	25	0.25	SS-L-11	4	21.0	4	4	3	1	3	3	3	3	4	3	2
4	26	1.5	SS-L-16	4	13.0	4	4	3	3	4	2	4	2	2	2	3
4	27	0.5	SS-C-25	4	23.0	2	4	4	1	4	3	2	3	4	3	4
4	28	0.5	SS-C-24	4	15.0	2	3	3	1	2	2	3	2	3	1	3
4	29	0.9	SS-C-23	4	17.0	2	4	3	1	3	2	3	2	2	2	3
4	30	0.25	SS-C-22	4	14.0	2	4	3	2	4	2	3	2	2	1	2
5	31	2.8	SS-C-32A	1	77.0	1	1	2	2	1	2	1	2	2	1	2
5	32	0.25	SS-L-33	1	69.0	1	1	2	4	2	2	3	3	2	2	2
5	33	0.25	SS-L-4	1	76.0	3	1	1	4	2	3	2	3	3	3	2
5	34	0.25	SS-C-29	1	70.0	1	1	1	4	1	1	1	2	2	2	2
5	35	2	SS-C-22A	1	57.0	1	2	1	1	1	3	2	2	1	2	1
5	36	0.95	SS-L-30	2	45.0	1	1	2	3	1	2	2	2	2	2	1
5	37	1.25	SS-L-19	2	37.0	1	3	2	4	1	1	2	2	1	1	2
5	38	0.25	SS-L-34	3	32.0	1	2	2	4	1	2	2	3	2	3	3
6	39	0.25	SS-R-1	1	61.0	3	3	2	3	2	3	2	1	1	3	1
6	40	0.25	SS-L-6	1	77.0	3	2	1	4	1	4	3	1	1	3	1
6	41	1.3	SS-R-3A	1	73.0	3	1	1	4	1	1	1	1	1	1	1
6	42	0.25	SS-R-2	1	70.0	3	2	1	4	3	2	1	1	1	2	1
6	43	0.25	SS-R-7	2	61.0	3	2	1	4	3	4	3	1	2	3	2
6	44	1.5	SS-L-15	2	41.0	4	3	2	4	4	1	2	1	2	1	2
6	45	0.5	SS-L-13	2	47.0	3	3	3	3	1	1	1	2	2	2	2
6	46	1.5	SS-R-17	2	47.0	4	3	1	3	1	3	2	2	2	2	2
6	47	0.45	SS-L-8	2	41.0	4	2	2	3	3	2	2	2	3	2	2
6	48	0.25	SS-R-3	2	55.0	4	4	4	4	1	1	1	1	1	1	1
7	49	3	SS-L-13A	1	74.0	3	2	1	1	3	1	1	2	2	2	2
7	50	5.2	SS-C-12B	1	75.0	3	1	1	1	1	1	1	1	1	1	1
7	51	4.5	SS-R-9B	1	83.0	2	1	1	2	1	1	1	1	1	1	1
7	52	0.75	SS-R-20	1	59.0	1	2	1	2	2	1	1	1	1	1	1
7	53	0.25	SS-C-32	2	52.0	1	1	1	3	2	1	1	1	1	1	1
7	54	2.9	SS-L-8A	2	57.0	3	2	2	2	2	1	1	1	1	1	1
7	55	0.25	SS-L-18	2	44.0	1	2	1	1	2	1	1	1	1	1	1

Figure 3: Depth of Sediment (ft) Collection to Mean of the Samples Identified in the Contamination Groups

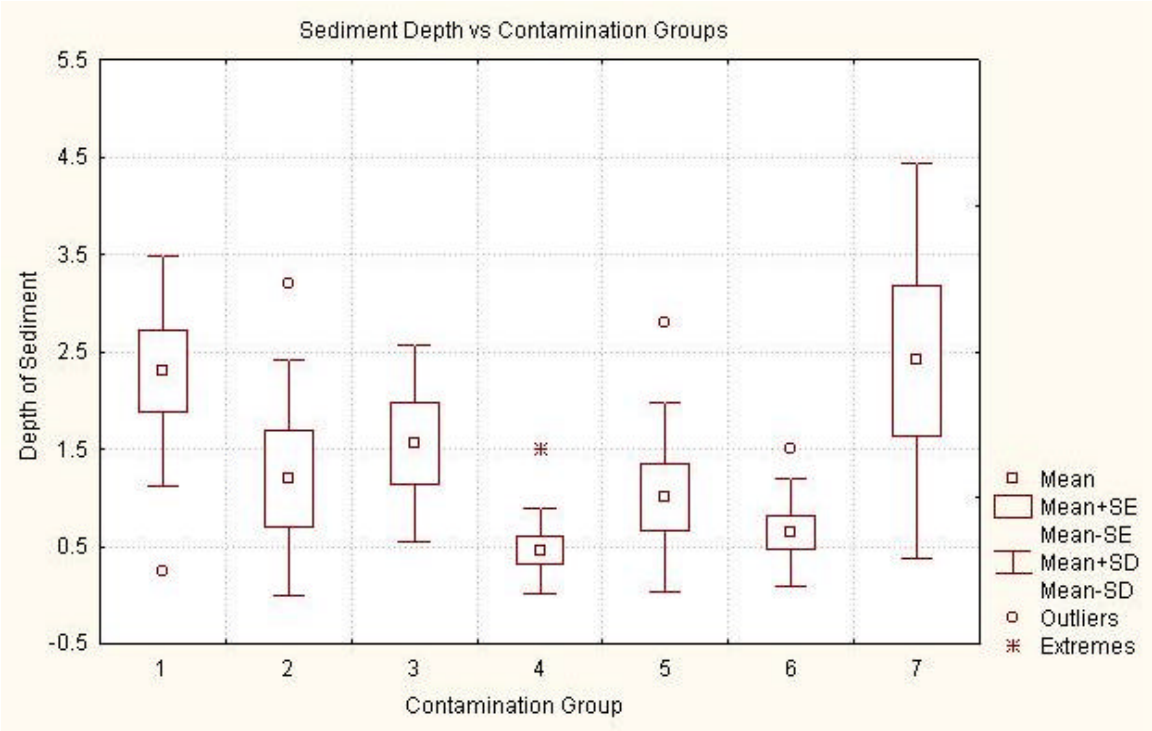


Figure 4: Mean Percent Total Volatile Solids (TVS) of the Samples Identified in the Contamination Groups

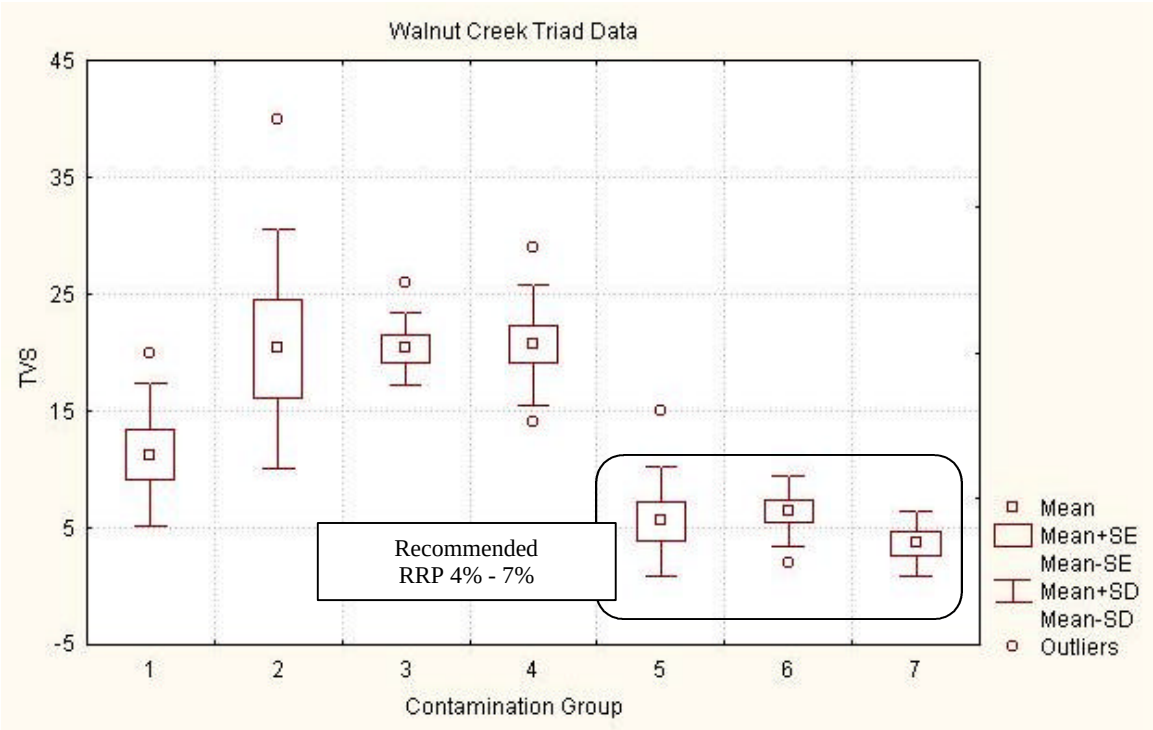


Figure 5: Percent Total Solids (TS) to the Mean of the Samples Identified in the Contamination Groups

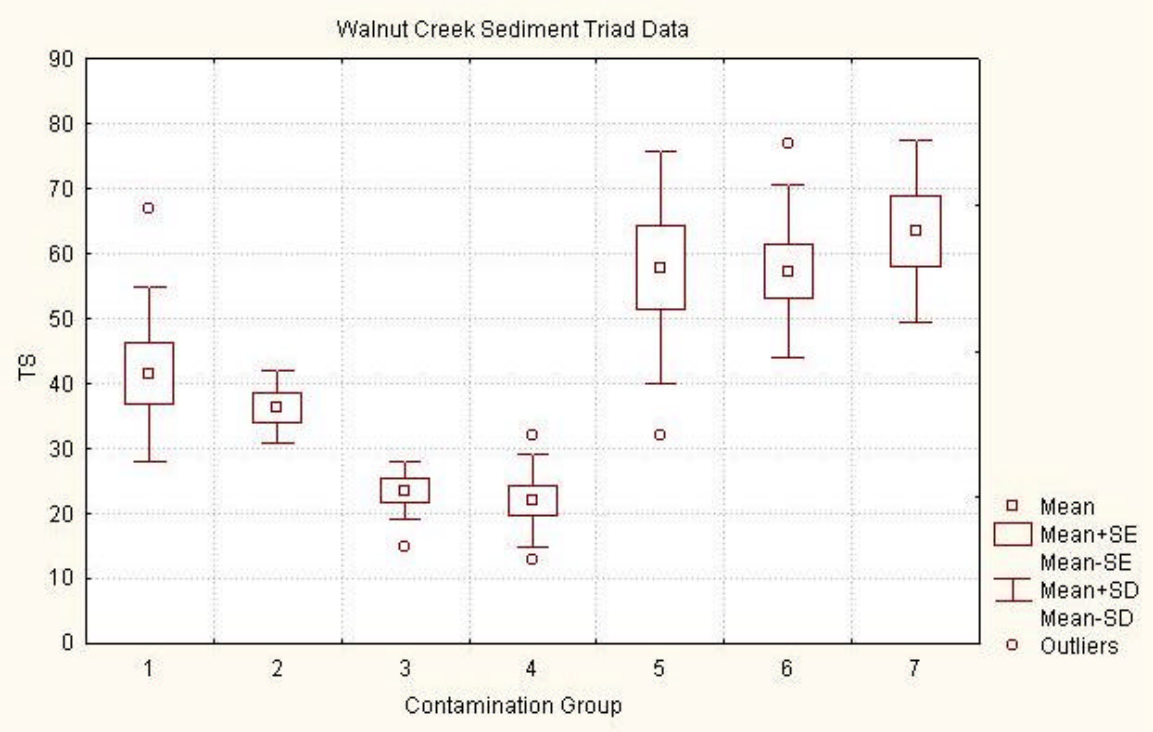


Figure 6: Total Organic Carbon (TOC) (mg/kg) to the Mean of the Samples Identified in the Contamination Groups

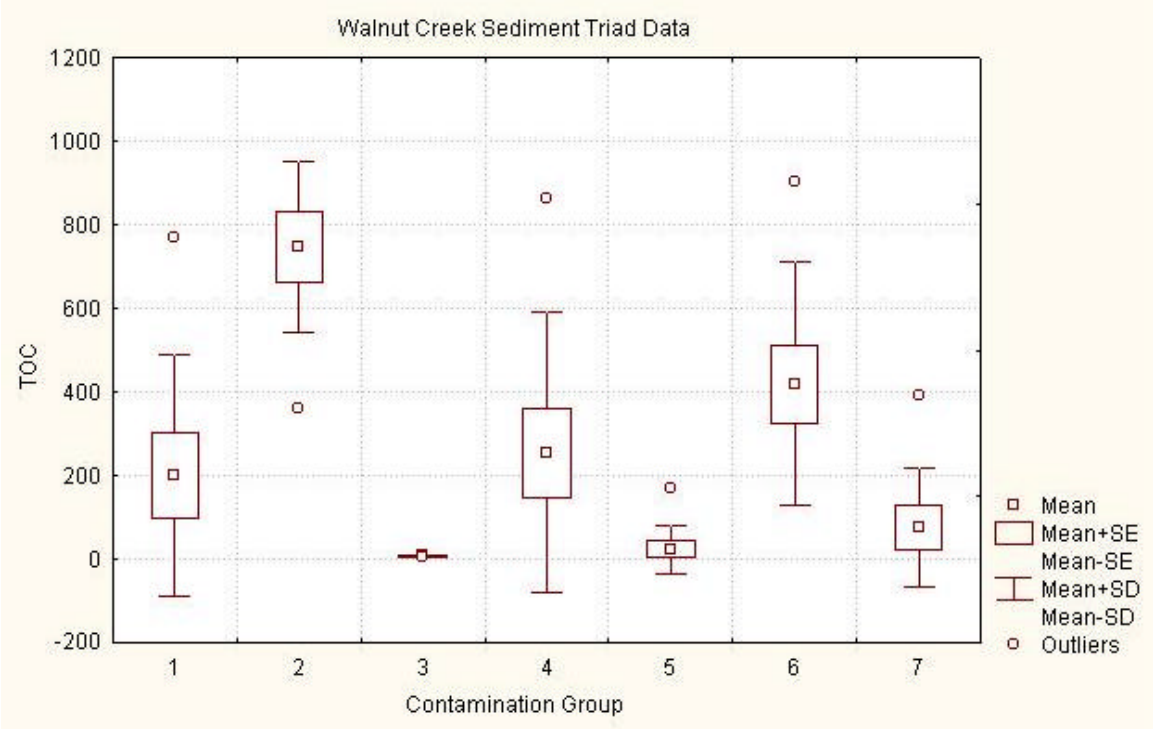


Figure 7: Mean Concentration (mg/kg) of NH3-N of the Samples Identified in the Contamination Groups

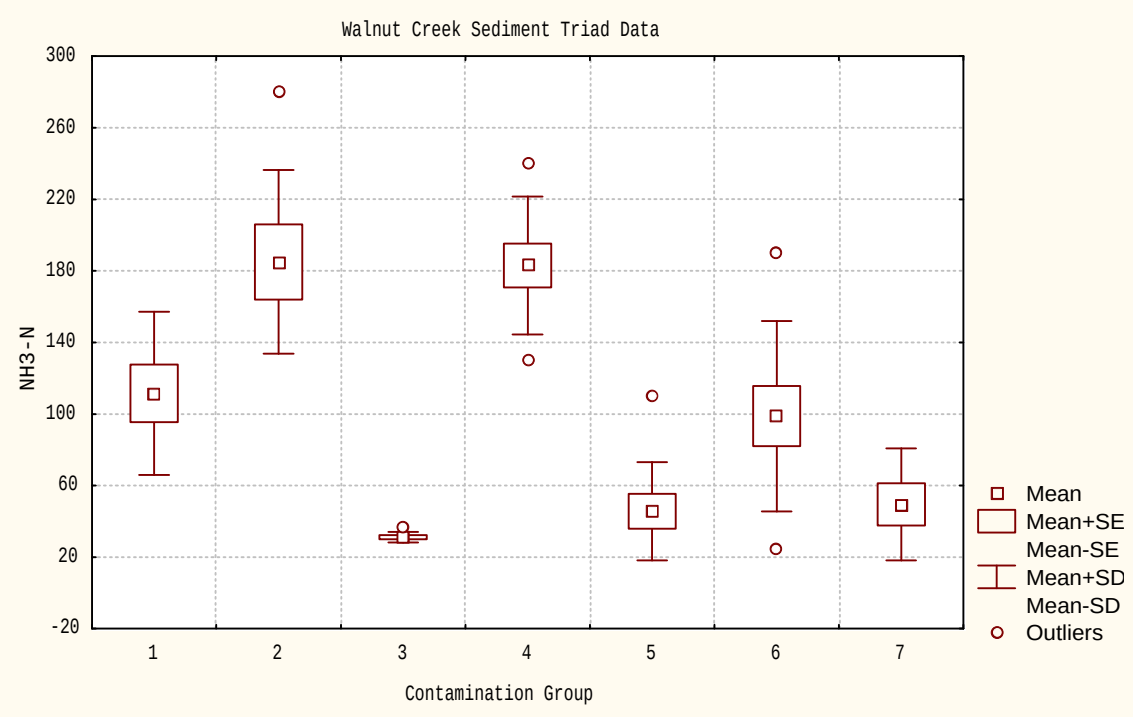


Figure 8: Mean Concentration (mg/kg) of Total Kjeldahl Nitrogen (TKN) of the Samples Identified in the Contamination Groups

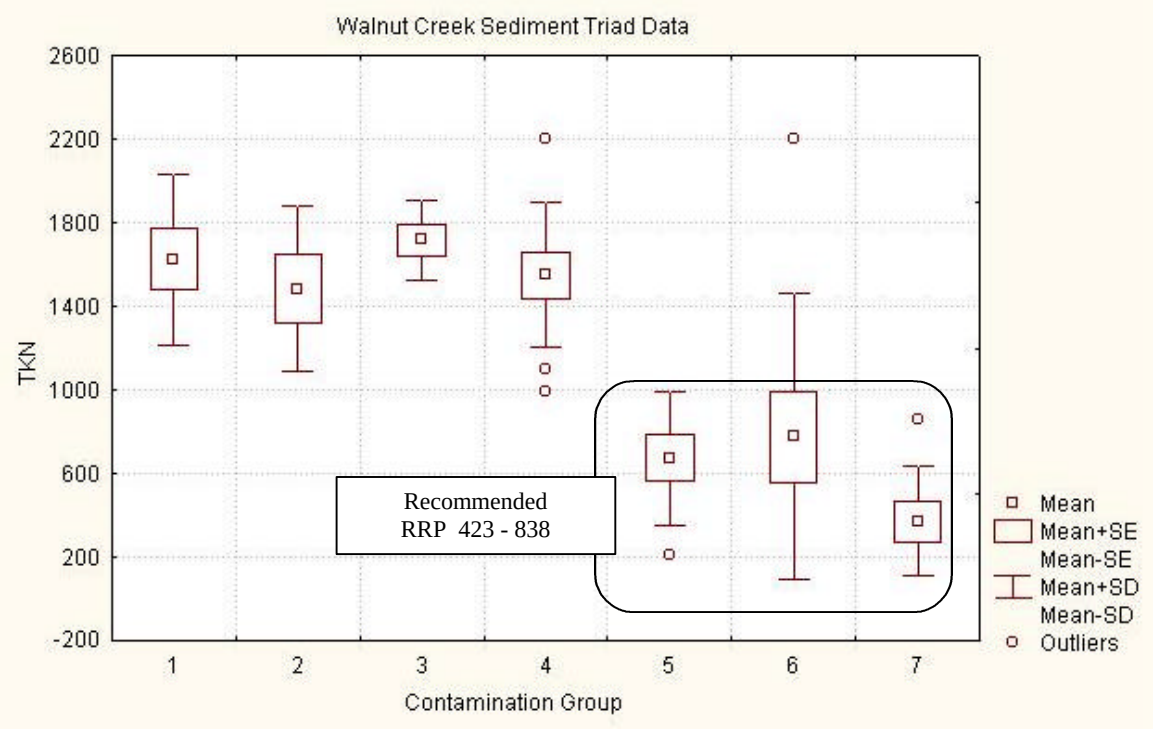


Figure 9: Mean Concentration (mg/kg) of NO2+NO3-N of the Samples Identified in the Contamination Groups

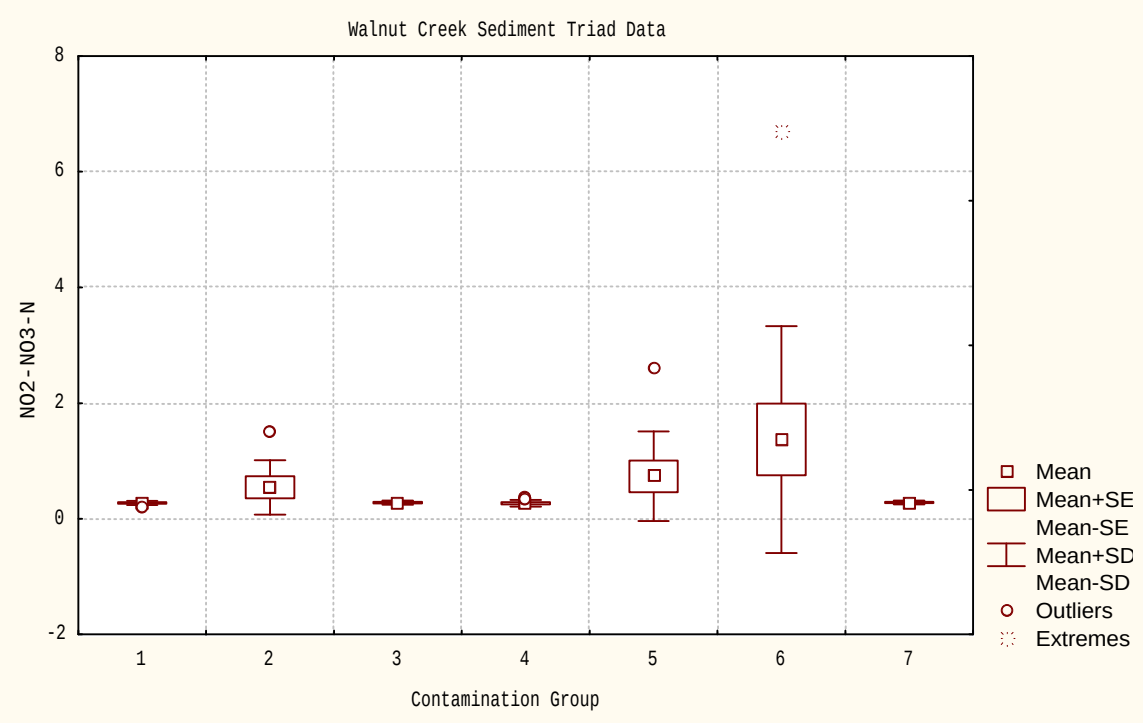


Figure 10: Mean Concentration (mg/kg) of Total-P of the Samples Identified in the Contamination Groups

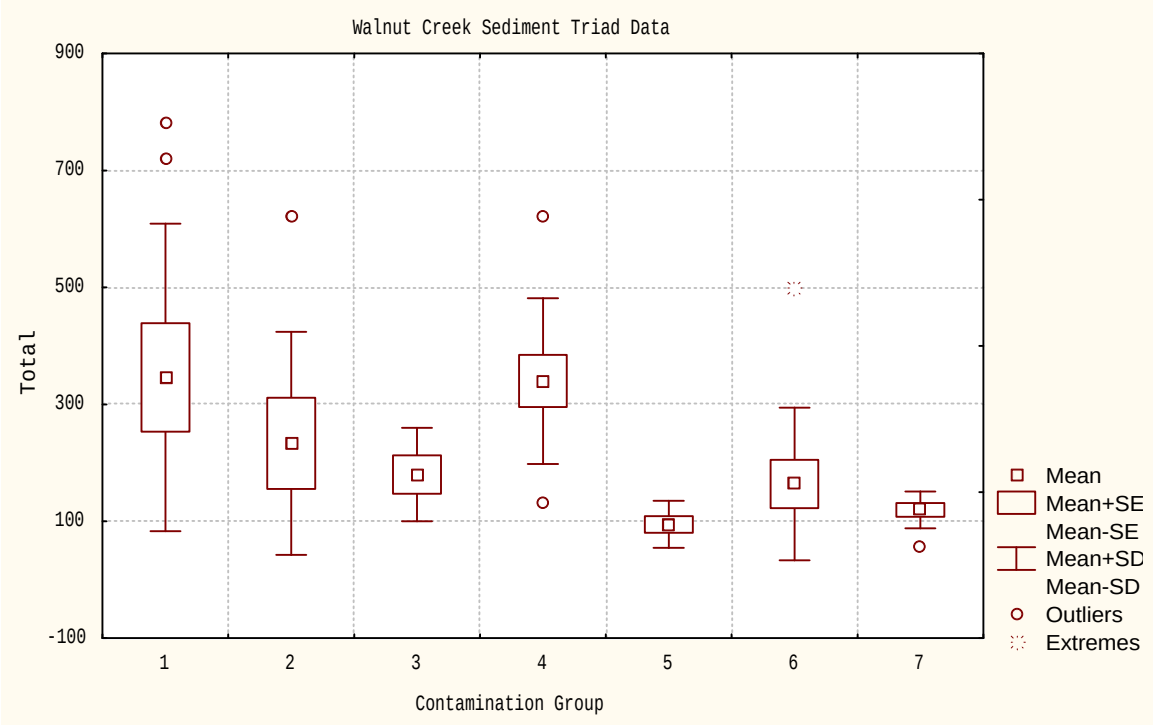


Figure 11: Mean Concentration (mg/kg) of Chromium of the Samples Identified in the Contamination Groups

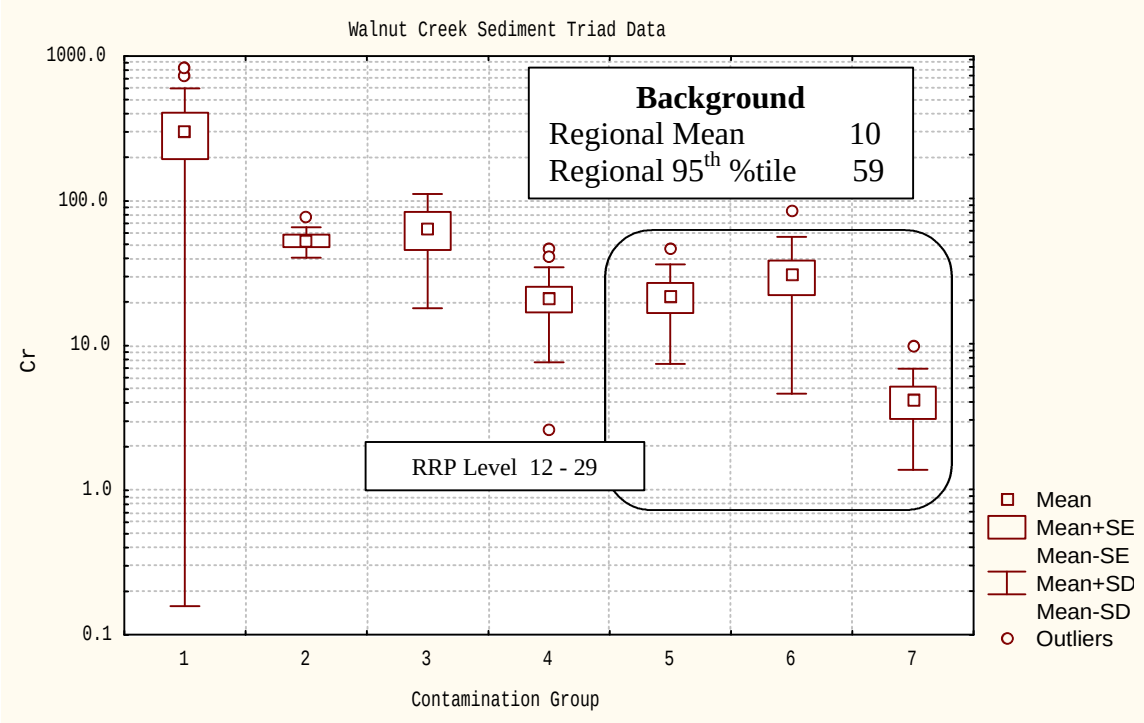


Figure 12: Mean Concentration (mg/kg) of Copper of the Samples Identified in the Contamination Groups

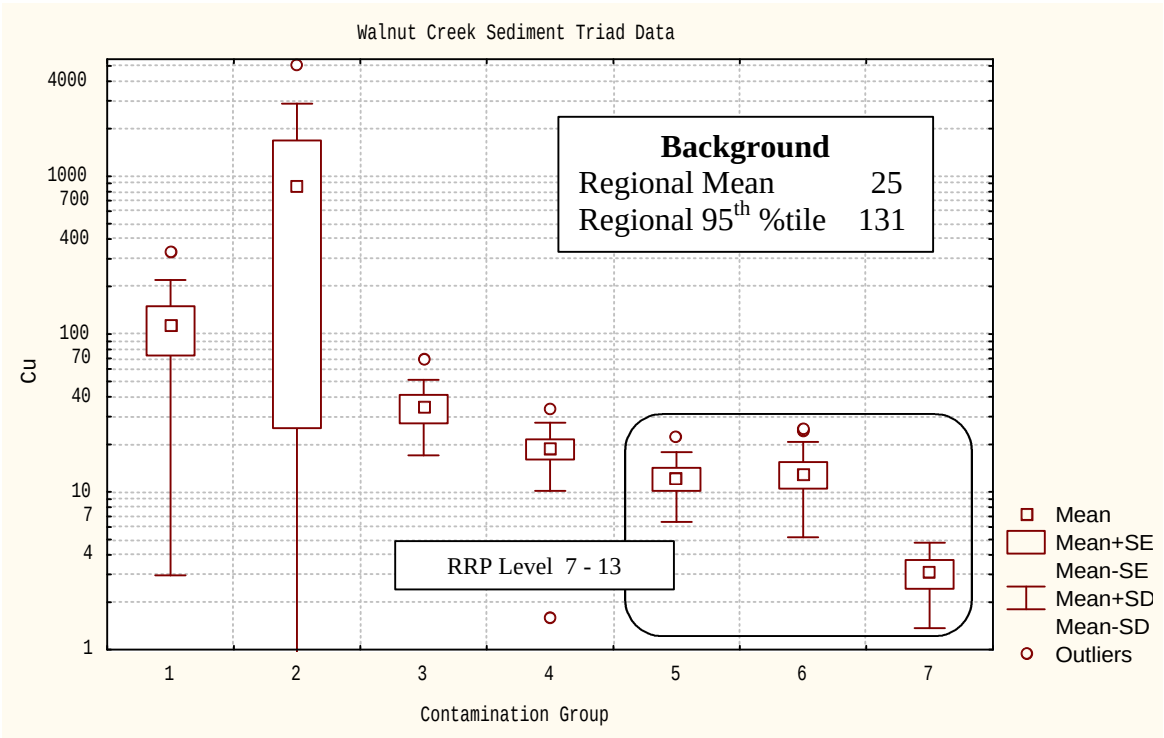


Figure 13: Mean Concentration (mg/kg) of Lead of the Samples Identified in the Contamination Groups

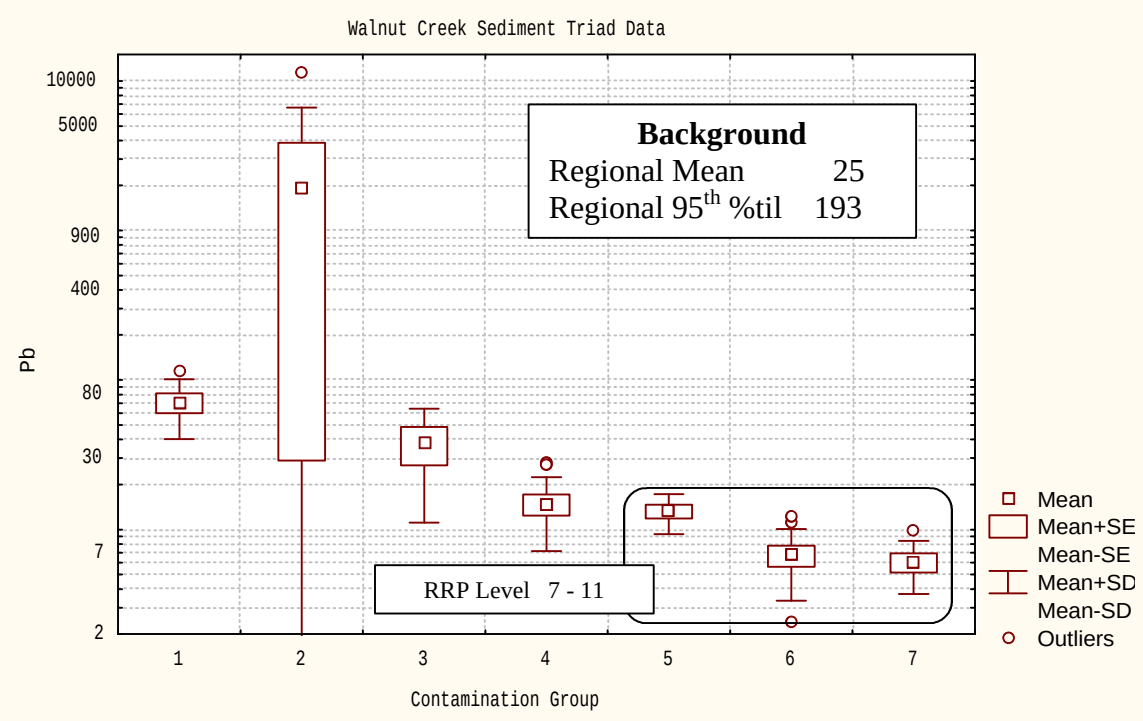


Figure 14: Mean Concentration (mg/kg) of Mercury of the Samples Identified in the Contamination Group

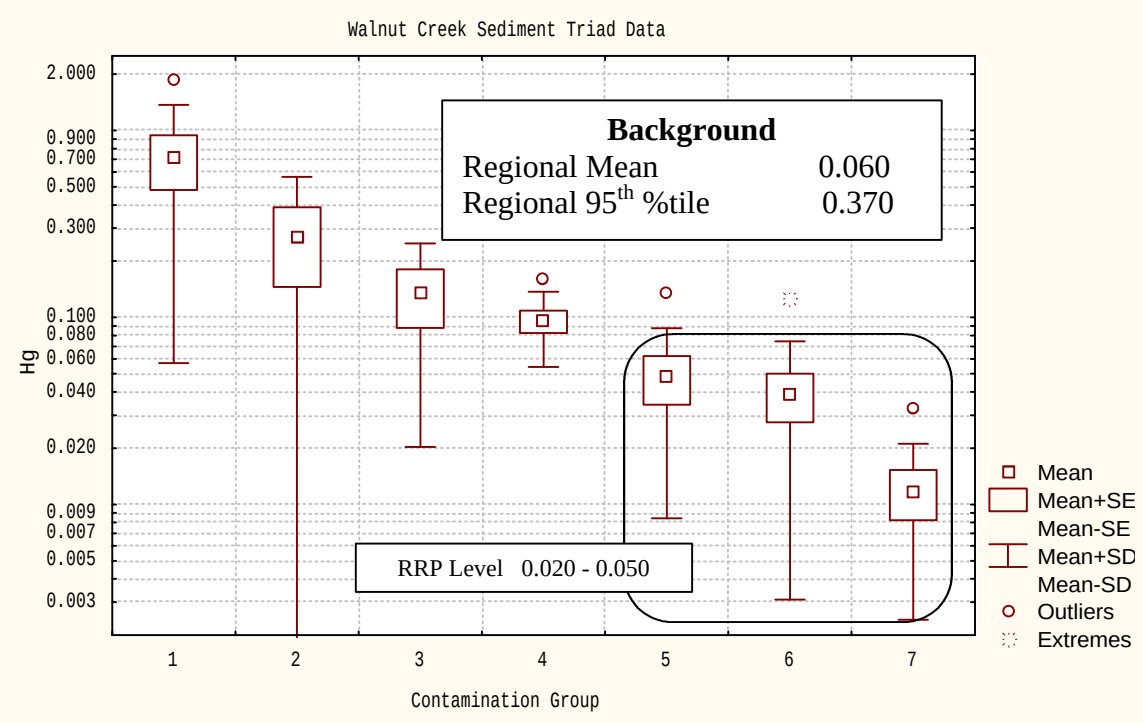


Figure 15: Mean Concentration (mg/kg) of Nickel of the Samples Identified in the Contamination Group

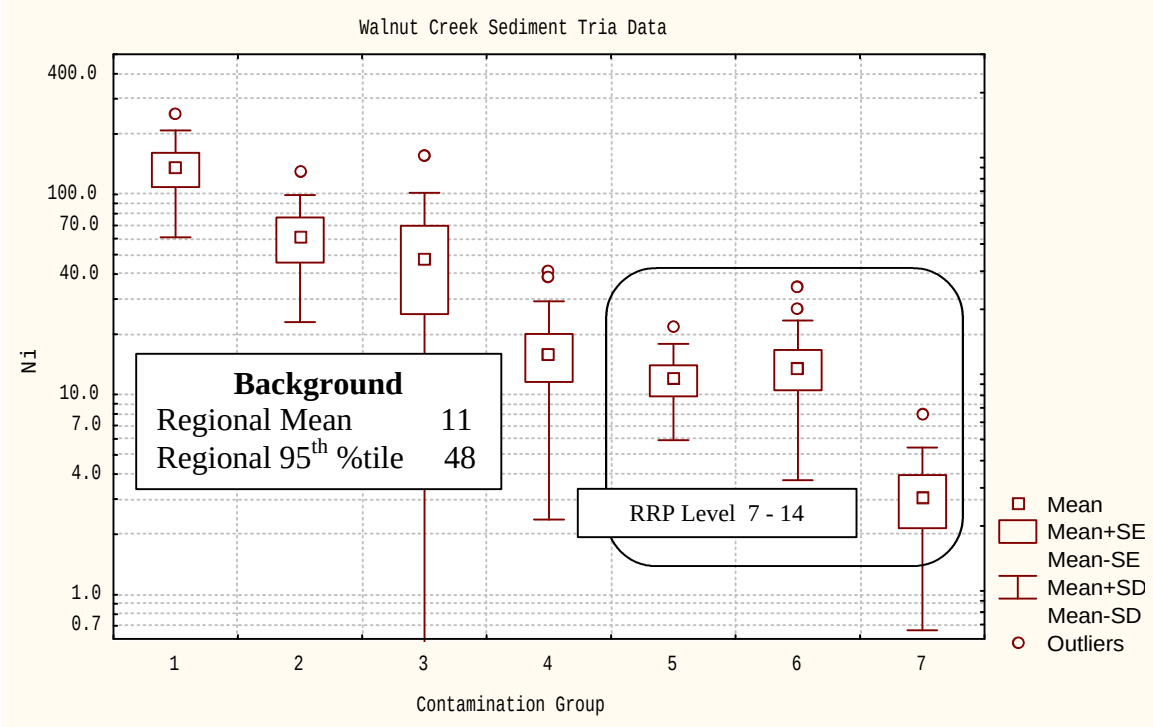
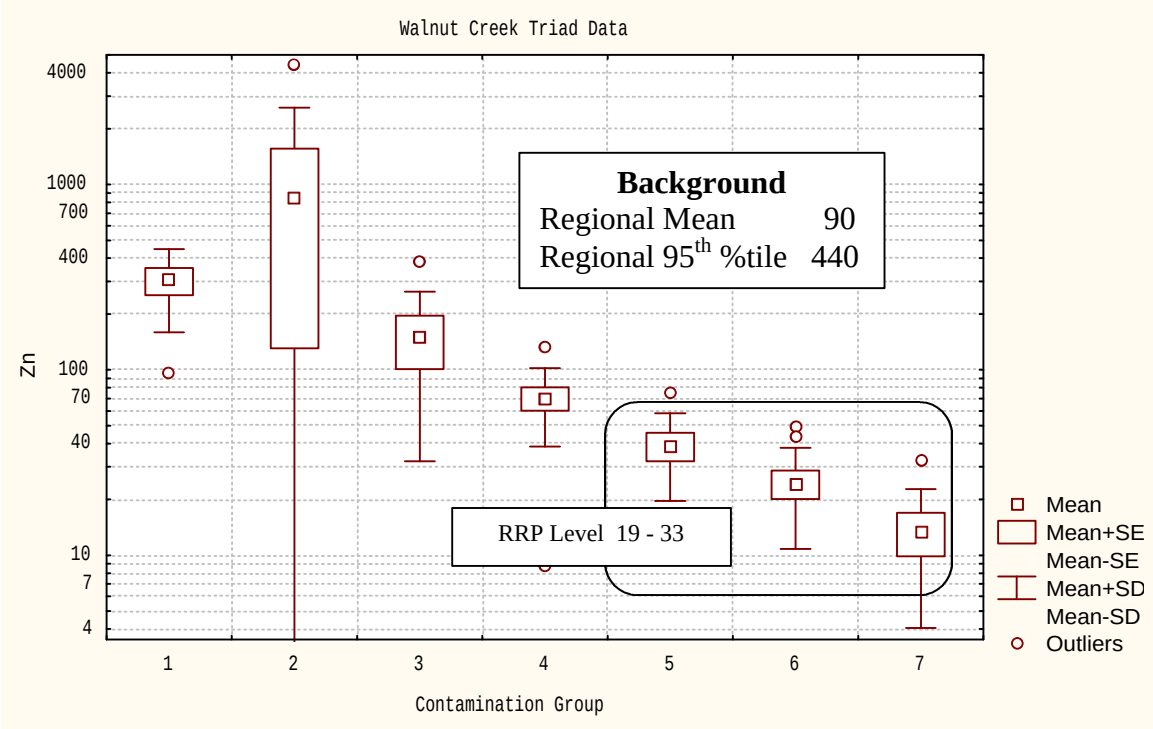


Figure 16: Mean Concentration (mg/kg) of Zinc of the Samples Identified in the Contamination Group



Appendix A: Data From: Table 3: From: *Stream Report Walnut Creek Downstream of the Warsaw Wastewater Treatment Plant Warsaw, Indiana*. Prepared for: City of Warsaw; Valentine Miner & Lemon, LLP; Plews Shadley Racher & Braun. By Triad Engineering Incorporated, May 2003

rank	site	final grp	TVS	TS	TOC	NH3-N	TKN	NO2+NO3-N	T-P	Cr	Cu	Pb	Hg	Ni	Zn
28	SS-C-23A	1	4.7	67.0	4	160	1200	0.23	150	137	47.9	38.6	0.9	42.6	96.1
12	SS-C-12AD	1	4.8	50.0	410	73	1300	0.21	160	123	35.8	42.2	0.128	110	121
12	SS-C-12A	1	6.4	39.0	382	130	1400	0.32	240	188	49.3	54.7	0.25	114	346
27	SS-C-24A	1	9.3	49.0	7	120	1400	0.27	210	835	331	110	1.85	252	460
17	SS-R-9	1	11.0	36.0	769	130	1400	0.29	120	140	79.9	59.7	0.408	65.1	279
24	SS-C-27B	1	16.0	37.0	7	50	1900	0.31	390	730	224	114	1.54	224	355
26	SS-C-25A	1	18.0	28.0	10	170	2200	0.29	720	89.1	31	52.8	0.197	103	272
24	SS-C-27A	1	20.0	26.0	9	58.9	2200	0.28	780	161	92.4	93.6	0.428	169	501
15	SS-L-16A	2	12.0	45.0	359	140	1300	0.37	140	49	16.8	15	0.74	17.5	62
16	SS-L-10	2	15.0	30.0	813	160	1100	0.32	180	41.2	26	24.1	0.0779	73.4	176
11	SS-L-14	2	16.0	39.0	723	280	1800	0.44	620	50.9	24.5	70	0.126	49.3	229
16	SS-L-10A	2	16.0	35.0	762	200	1800	0.33	180	57.6	27.3	16.7	0.54	50.3	115
17	SS-R-9A	2	23.0	31.0	920	180	1900	0.3	160	76.2	32.3	18.9	0.0946	46.4	75.2
8	SS-R-5	2	40.0	38.0	909	150	1000	1.5	120	43.8	4990	11500	0.0246	130	4420
18	SS-C-31	3	17.0	27.0	7	30	1600	0.33	150	110	28	71.7	0.219	42.3	95.4
23	SS-C-28A	3	19.0	26.0	7	30	1500	0.27	120	53.6	24.5	27.7	0.008	40.8	141
25	SS-C-26A	3	19.0	26.0	8	30	2000	0.25	140	135	68.4	71.7	0.32	155	382
25	SS-C-26	3	20.0	24.0	5	30	1900	0.32	110	37.7	24.2	18.1	0.0789	17.7	92.8
24	SS-C-27	3	21.0	23.0	8	37.1	1700	0.25	300	32	26.8	20	0.0729	17.1	93.8
23	SS-C-28	3	26.0	15.0	8	30	1600	0.26	260	20.4	32.8	17.1	0.108	11.4	85
13	SS-R-11	4	14.0	30.0	486	220	1700	0.26	400	12.2	17.9	28.3	0.144	13.3	80.8
12	SS-C-12	4	15.0	32.0	509	170	1400	0.28	280	16.3	13	10.1	0.0648	12.9	50.3
31	SS-C-21D	4	16.0	28.0	4	130	990	0.36	450	24.3	13.5	15.6	0.066	38.7	96
31	SS-C-21	4	17.0	27.0	4	140	1100	0.31	620	2.6	1.6	5.3	0.1	1	8.8
26	SS-C-25	4	20.0	23.0	6	180	2200	0.2	450	40.9	16.5	27.4	0.146	41.4	133
14	SS-L-11	4	23.0	21.0	864	180	1700	0.21	230	46.7	22.7	16.2	0.16	15.8	61.5
27	SS-C-24	4	23.0	15.0	9	140	1700	0.23	130	14.2	25.4	12	0.105	7.48	74.1
28	SS-C-23	4	23.0	17.0	7	220	1700	0.21	230	16	19.4	12.5	0.057	9.56	65.8
29	SS-C-22	4	27.0	14.0	8	240	1600	0.28	300	13.6	24.5	8.8	0.052	6.84	61.1
15	SS-L-16	4	29.0	13.0	659	210	1400	0.35	310	24.9	33.6	11.4	0.063	11.1	71.9
22	SS-C-29	5	1.5	70.0	2	30	230	0.51	65	8.7	5.5	12	0.0331	7.61	25.7
9	SS-L-4	5	2.0	76.0	167	34	210	2.6	150	45.8	18.7	18	0.134	19.3	45.4
5	SS-L-33	5	2.9	69.0	1	30	930	0.66	150	23.9	22.3	18	0.0627	10.8	54.4
1	SS-C-32A	5	3.2	77.0	5	30	710	0.3	84	16.6	6.6	8.6	0.028	6.58	29.9

29	SS-C-22A	5	4.0	57.0	2	53	590	0.21	45	33.1	11	10	0.02	12	18
21	SS-L-30	5	6.4	45.0	3	30	1100	0.36	55	31.9	12	13	0.0635	12	20
33	SS-L-19	5	10.0	37.0	4	110	890	0.76	100	2.6	10.4	9.3	0.008	5	43.9
6	SS-L-34	5	15.0	32.0	5	48.2	740	0.48	110	12.7	10.8	17.2	0.0354	21.9	74.4
20	SS-R-3A	6	2.0	73.0	205	25	290	2.3	70	8	4.8	5	0.0086	6.7	14
30	SS-R-2	6	2.0	70.0	146	41	150	0.71	200	19	6	5.2	0.008	8.52	7.4
2	SS-R-1	6	4.4	61.0	134	100	680	0.44	150	33.5	16.4	6.5	0.0146	18	20
4	SS-L-6	6	4.6	77.0	142	62	120	0.79	70	84.2	25	2.4	0.0197	34.5	16.7
18	SS-R-17	6	7.1	47.0	778	130	600	0.33	68	43	12	12.4	0.0562	13	44
19	SS-L-8	6	7.5	41.0	901	92	660	0.33	180	23.5	19	9.5	0.125	9.07	49
20	SS-R-3	6	8.5	55.0	622	190	2200	0.89	110	10.6	5.64	2.6	0.0177	6.76	12.5
7	SS-L-15	6	9.1	41.0	650	150	1300	0.9	500	8.3	9.2	5.8	0.0561	4.78	26
3	SS-R-7	6	9.5	61.0	290	58	260	6.7	210	62.6	24.6	6.5	0.0321	26.6	23.1
10	SS-L-13	6	9.8	47.0	319	140	1500	0.32	80	12	7.05	11.3	0.0498	8.01	30.7
12	SS-C-12B	7	1.0	75.0	78	22	200	0.25	57	2.4	1.1	2.5	0.008	1.9	6.3
17	SS-R-9B	7	1.0	83.0	9	5	50	0.3	110	2.6	3.8	5.3	0.008	4.2	12.2
10	SS-L-13A	7	1.5	74.0	41	70	190	0.26	160	10	5.4	10	0.0329	7.95	32
34	SS-R-20	7	2.5	59.0	1	52	400	0.31	130	2.5	1.5	5.1	0.008	1.3	8.2
1	SS-C-32	7	5.3	52.0	1	30	420	0.32	130	5	5	5.3	0.0094	1.9	11.8
19	SS-L-8A	7	6.4	57.0	393	86	860	0.3	130	3.9	2	7.8	0.008	1.3	4.9
32	SS-L-18	7	7.9	44.0	4	81	480	0.23	120	2.6	2.7	6.4	0.008	2.8	18.4